GRINDING WITH CONTROLLED ROLL PRESSURE

by

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INTRODUCTION

The purpose of this study was to obtain basic information on grinding with maximum efficiency using controlled roll pressures. Measuring grinding pressure in place of "feel" for setting reduction rolls would eliminate some of the variables in grinding. In addition to this, physical and chemical changes could be determined accurately on flours produced with different pressures.

Madge (1948) conducted experiments on the power requirements, roll pressures, and extraction rate during the grinding operation. He studied a 9-inch by 30-inch Nordyke and Marmon roll stand with a roll differential of one and one-half to one, the fast roll operating at 450 r.p.m. using third middlings stock. Roll pressures were measured by an Oxweld pressure gauge placed on the free end of the slow roll in direct contact with the compound tension lever. Madge (1948) found that as the roll pressure was increased beyond a certain value, the horsepower requirements increased, but the amount of flour extracted from the stock was reduced. Also it was found that the amount of stock to the rolls could be increased or decreased without perceptible change in the gauge reading, but the extraction increased in direct ratio to the amount of stock ground.

Ziegler (1940) made a study of the effect of roll

pressure, roll differential, and temperature of stock on the diastatic activity of flour. He used an experimental mill on which the roll pressures and differential could be changed easily. Exact pressures could be applied since, in addition to the weights used, each of the two rolls was driven by a separate belt. The results of his work were as follows: (a) normal pressure used in the milling of coarse middlings is about 600 to 700 kg. per meter roll length; (b) in the absence of roll differential or with a polished surface, no significant increase in diastatic activity was caused by milling; (c) in the presence of a differential, the rougher the surface and the higher the roll pressure, the greater the increase in diastatic activity; (d) the smoother the reduction rolls, even if they do not touch each other, the more heat they develop in milling. Roll temperature below 20°C. had more effect on diastatic activity per degree increase than above that temperature. Although the product was only in contact with the rolls for approximately one-one hundredth of a second, the effect of roll surface and temperature on diastatic activity was quite noticeable.

Studies by Alsberg and Griffing (1925) indicate over-grinding of flour injures the starch granules to the point that a part of the starch swells and disperses when the flour is doughed. They also found that moderate over-grinding may injure the starch granules without affecting the gluten. In the case of one flour examined, absorption was appreciably

increased without material effect upon the baking strength.

The horsepower required in the milling process varies with the size of the mill, types of bearings used, lubrication used, material to be ground, etc. Dedrick (1924) found from his studies that approximately 60 percent of the power was taken for the rolls or grinding, and 40 percent was taken for the balance of the mill. This was based on plain type bearings.

Lockwood (1948) states that roller mills consumed nearly 70 percent of the power required in the flour mill itself. He also contends that it takes approximately 0.5 B.H.P. for a 40-inch roll with no feed. This estimate might be doubled if the roller mill is not in first class condition.

For this investigation it was necessary to have a suitable means for measuring roll pressure. It seemed desirable to use a gauge similar to that used by Madge (1948), but his gauge was of special construction; therefore, considerable expense would have been entailed. It was learned that Mr. A. T. Hughes had invented another type of gauge known as the Statimeter that had been used to measure roll pressures in English mills. Through the kindness and cooperation of Mr. A. T. Hughes of England, and Mr. S. H. Hughes of the Statimeter Corporation of America, gauges were made available for the investigation of roll pressures to the Department of Milling Industry.

MATERIALS AND METHODS

All the studies reported on were conducted on third middlings stock from commercially milled hard red winter wheat, obtained from the Shellabarger Mill and Elevator Company, Salina, Kansas. All the stock was shipped in steel drums to prevent loss of moisture.

This investigation was divided into four divisions:

1. The measurement of roll pressure.
2. The development of a suitable power panel for measuring input horsepower.
3. The development of grinding and sampling procedures.
4. The noting of the differences in the physical and the chemical properties of the flours produced.

Measuring Roll Pressure

The Statimeter (English patent 398,687) was found to be a fairly satisfactory gauge for measuring roll pressure. The Statimeter consists of a flexible annular tube filled with a liquid mixture of glycerine and water which has been deaerated before being enclosed in a rigid casing. The casing is formed by two cup-shaped members, one telescoping within the other. Each member receives part of the flexible container. The liquid in the tube is piped by means of a capillary tube to a gauge of special construction, designed to withstand

machine vibrations. Pressure applied to either end of the cup-shaped rigid casing is instantly transmitted to and indicated upon the gauge.

The ability of a confined and filled rubber tube (e.g., the thin-walled inner tube of an automobile tire) to support heavy loads and take punishment is well known, and the Statimeter makes use of this factor. By mounting the Statimeter on the spring tension rod of a roll stand, it becomes an integral part of the machine.

To mount the gauges, it is necessary to remove the spring tension rods from each end of the roll stand. The rods must be cut at the proper point where the gauge will have sufficient clearance when mounted on the roll stand. After cutting the rods, they must be threaded at the cut ends and screwed into the Statimeter casings and locked in place. Care must be taken that the two ends do not touch inside the casings.

The tension rod is then mounted on the roll stand in the normal way. The Wolf roller mill, with rolls seven inches in diameter and 14 inches long, does not have sufficient clearance for the gauges; therefore it was necessary to modify the roll feeder drive. This was done by removing the two plain bearing hangers and mounting two anti-friction bearings on the roll housing. This would not be necessary on the larger roll stands used in most commercial mills.

To set the springs with equal tension, it is necessary to place the rolls in tram and in the grinding position,

touching each other. The spring tension housings are then adjusted against the springs, and set with equal pressures that are beyond the grinding pressure expected to be used. The adjustment hand wheels are then turned until the pressures read zero on both gauges. At this point, the rolls are parallel.

Plate I shows the Statimeter mounted on the Kansas State College's Wolf 7-inch x 14-inch roller mill, which was used for this investigation.

Figure 1 shows the position of the Statimeter in relation to the grinding rolls. By the use of the principle of moments the actual pressure on the rolls was calculated. The Statimeter reads in pounds pressure, and the gauges used for this investigation were calibrated from zero to 500 pounds.

Table 1 has the conversion from Statimeter readings to pounds per linear inch of roll surface. This unit of pressure seemed most desirable since it could be standardized to make further studies with different gauges.

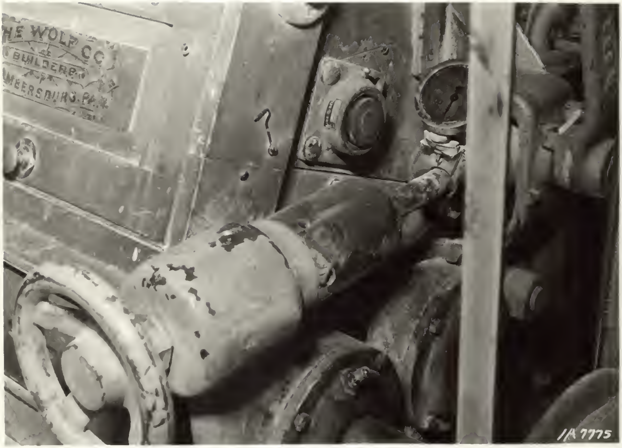
Although the rolls are 14 inches in length, it is not fully utilized since the roll saddles on the end take up some of the roll surface. However, this would be the case in most all roller mill housings, and the amount would be about the same. For this reason, the pressure was figured on the full 14 inches of roll surface.

Normally, on the style "A" roller mill drive, the force of the belt tension would affect the roll pressure. To

EXPLANATION OF PLATE I

The Statimeter gauge mounted on the Wolf roller mill.

PLATE I



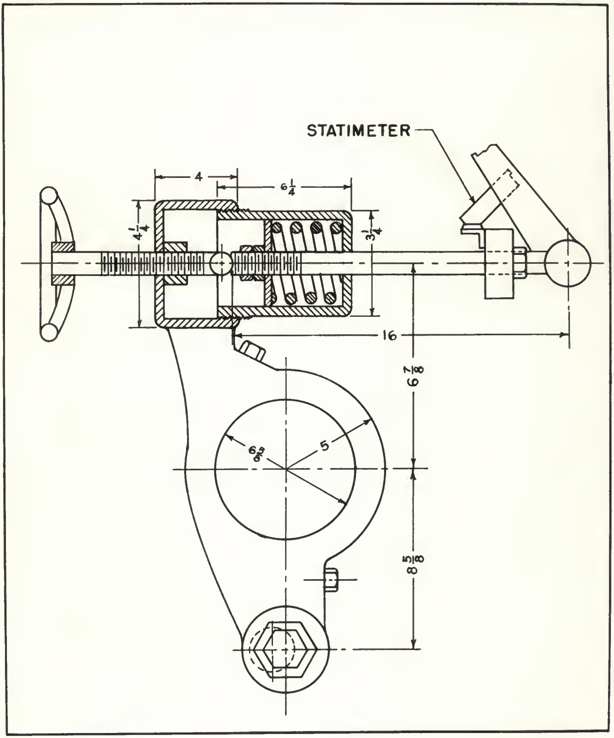


FIG. I. WOLF ROLLER MILL ADJUSTMENT.

Table 1. Conversion of Statimeter readings to actual pressure in pounds per linear inch of roll surface.

Statimeter pressure reading in pounds on each end of the roll	Actual pounds pressure on each end of roll	Actual roll pressure in pounds per linear inch of roll surface*
50	90.1	12.87
100	180.2	25.74
150	270.3	38.61
200	360.4	51.48
250	450.5	64.35
300	540.6	77.22
350	630.7	90.09
400	720.8	102.96

*Calculated on basis of 14 inches of roll surface.

eliminate this force, the V-belt drive was installed directly above the drive pulley. Figure 2 shows the drive designed and used for this investigation.

After the two Statimeters were installed and operated on some test runs, it was necessary to work on the roller mill stand so the locknuts on the eccentric did not restrict the movement of the swing arms on the tramming eccentric. It was also necessary to see that the springs and spring tension rod were as free as possible from the spring tension housing. Figure 3 shows the Statimeter mounted on the tension rod.

Power Panel

The portable test panel designed for this work included features that made it useful for all types of power readings. The portable test panel (Plate II and Fig. 4) contains a voltmeter, an ammeter, a polyphase watt meter, a polyphase watt-hour meter and a 15-minute kilowatt demand meter attachment (all in one case), a polyphase power-factor meter, a current transformer shorting switch (marked run-off switch) and two standard five-amperes cartridge fuses mounted on the back of the panel.

The voltmeter and the potential elements of the watt-meter, watt-hour meter and demand meter and power factor meter, are rated at 300 volts. They were connected directly to the motor line wires through the portable potential lead.

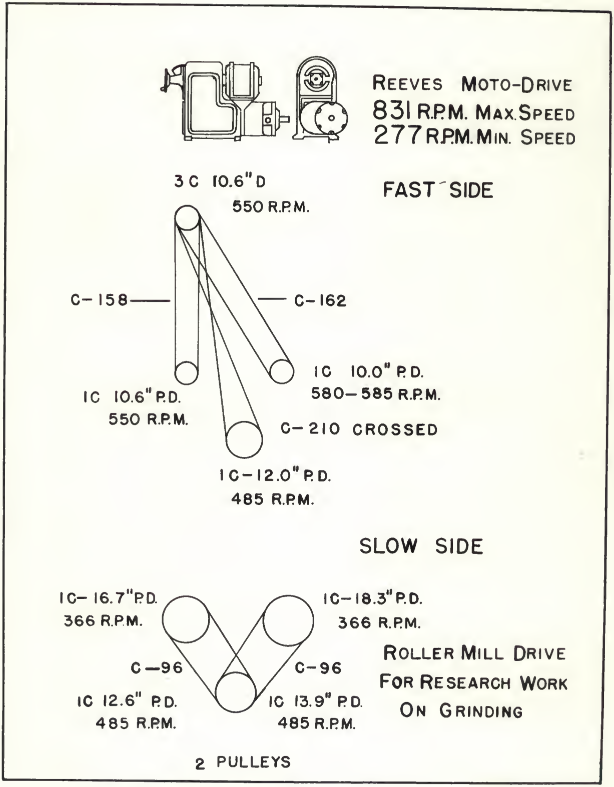


FIG. 2. ROLLER MILL DRIVE.

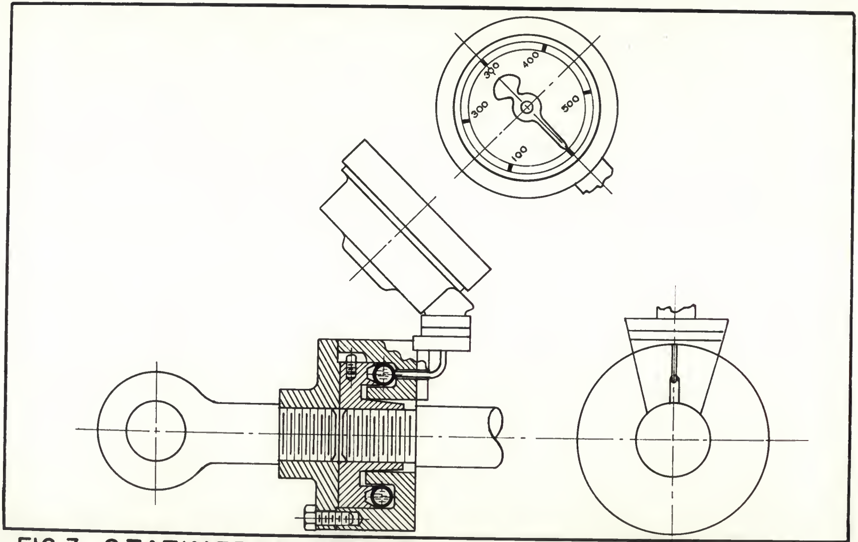
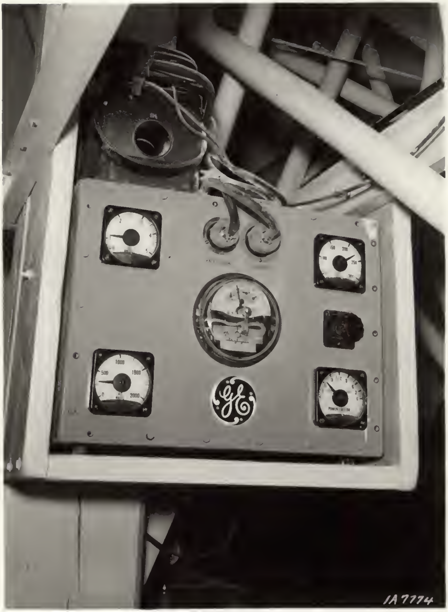


FIG.3. STATIMETER MOUNTED ON TENSION ROD.
SCALE: 9" = 1'-0"

EXPLANATION OF PLATE II

Portable power test panel. Current transformers located on top of case.

PLATE II



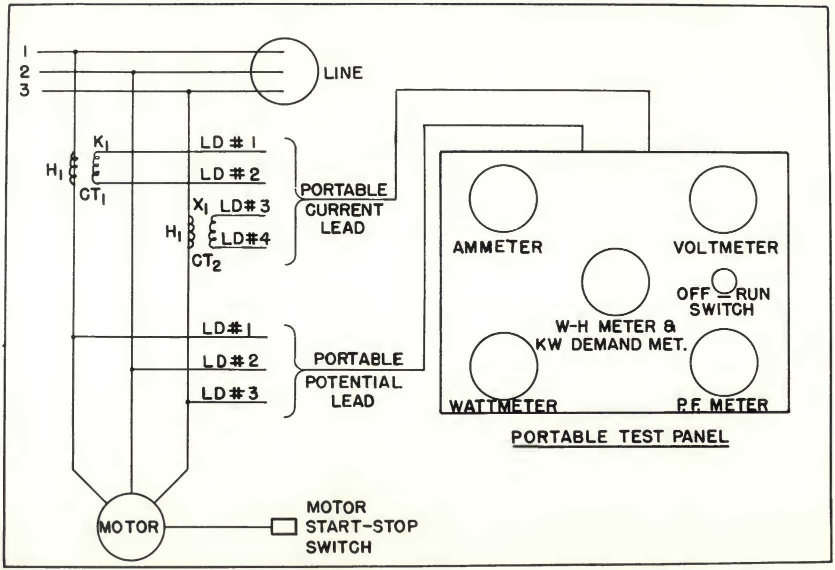


FIG. 4. PORTABLE POWER TEST PANEL.

The ammeter and the current elements of the watt meter, watt-hour meter and demand meter, and power factor meter, are rated at five amperes. They were connected through the portable current lead to the current transformer (CT) secondaries. The primaries of the current transformers were connected into two of the three motor line wires. The current transformers were used to reduce the load current down to a value that could be read safely on the five ampere range meters. A current transformer ratio of 20:5 worked satisfactorily for this investigation. Within the panel, a five-ampere fuse was connected in series with each of the two current transformer secondaries. These fuses protect the meters from excessive current. The panel should never be over-fused. The run-off switch short-circuited each of the current transformer secondaries at the panel ahead of the fuses when it was in the off position. It was used to protect the meters and fuses while the motor was being started. The starting currents of induction motors are from five to eight times the normal full load currents.

The voltmeter reads the voltage in volts between any two of the three wires to the motor. This voltage during the work was uniform at 230 volts.

To report the results for practical information, the input horsepower requirements were calculated by use of the following formula:

$$\text{Input horsepower} = \frac{\text{watts}}{746}.$$

Motor input load characteristics are determined from the portable test panel meter readings as follows:

Voltage, volts = voltmeter reading as read

Current, amperes = ammeter readings x CT ratio

Power, watts = ammeter reading x CT ratio

Energy consumed during test period, kilowatt hours (KWH) = watt-hour meter reading x CT ratio (after 15 minutes of operation).

Power factor (pf) = power factor meter reading as read or may be calculated from the following formula:

$$\text{Power factor} = \frac{\text{Wattmeter reading}}{\sqrt{3} \times \text{voltmeter reading} \times \text{ammeter reading}}$$

Readings were recorded on each run and are in Tables 2 and 3. Figure 5 shows the horsepower requirements with different roll pressures.

Grinding and Sampling Procedure

On preliminary runs, brushes were used for cleaning the rolls. Since they did not keep the rolls clean at high grinding pressures, they were replaced with metal scrapers. The metal scrapers worked satisfactorily at all times, and took considerably less power than the brushes. After modifying the feeder roll and checking it for a uniform feed, the tests were begun.

The rate of flow was kept constant at three pounds per

Table 2. Power panel readings for third middlings grinding tests with different roll pressures.

Power panel readings and calculations	Roll pressure in lbs./linear inch roll surface							
	12.87	25.74	38.61	51.48	64.35	77.22	90.09	102.96
Amps	1.2	1.8	2.0	2.2	2.7			
Amps x ct ratio	4.8	7.2	8.0	8.8	10.5			
Watts	350.0	610.0	680.0	760.0	925.0			
Watts x ct ratio	1400.0	2440.0	2720.0	3040.0	3700.0			
Horsepower	1.8	3.3	3.6	4.1	5.0			
Amps	1.5	1.8	2.0	2.3	2.5			
Amps x ct ratio	6.0	7.2	8.0	9.1	10.1			
Watts	500.0	600.0	700.0	800.0	900.0			
Watts x ct ratio	2000.0	2400.0	2800.0	3200.0	3600.0			
Horsepower	2.7	3.2	3.8	4.3	4.8			
Amps	1.3	1.5	1.9	2.2	2.5	2.8		
Amps x ct ratio	4.9	6.2	7.6	8.6	10.0	11.2		
Watts	360.0	500.0	650.0	740.0	860.0	1000.0		
Watts x ct ratio	1440.0	2000.0	2600.0	2960.0	3440.0	4000.0		
Horsepower	1.9	2.7	3.5	4.0	4.6	5.4		
Amps	1.3	1.6	2.0	2.2	2.5	2.7	2.7	
Amps x ct ratio	5.2	6.5	7.8	8.8	10.2	10.6	10.8	
Watts	385.0	605.0	680.0	760.0	890.0	928.0	953.0	
Watts x ct ratio	1540.0	2420.0	2720.0	3040.0	3560.0	3710.0	3810.0	
Horsepower	2.1	3.2	3.7	4.1	4.8	5.0	5.1	

Table 2. (concl.)

Power panel readings and calculations	Roll pressure in lbs./linear inch roll surface							
	12.87	25.74	38.61	51.48	64.35	77.22	90.09	102.96
Amps	1.3	1.5	1.8	1.9	2.2	2.4	2.6	
Amps x ct ratio	5.2	6.0	7.0	7.7	8.8	9.8	10.4	
Watts	410.0	495.0	600.0	660.0	763.0	850.0	885.0	
Watts x ct ratio	1640.0	1980.0	2400.0	2640.0	3050.0	3400.0	3540.0	
Horsepower	2.2	2.7	3.2	3.5	4.1	4.6	4.8	
Amps	1.4	1.6	1.8	2.0	2.2	2.6	2.9	
Amps x ct ratio	5.5	6.2	7.1	7.9	9.0	10.4	11.4	
Watts	442.5	525.0	613.0	685.0	770.0	900.0	1017.5	
Watts x ct ratio	1170.0	2100.0	2450.0	2740.0	3080.0	3600.0	4070.0	
Horsepower	2.4	2.8	3.3	3.7	4.2	4.8	5.5	
Amps	1.2	1.5	1.8	2.0	2.6	2.7	3.1	
Amps x ct ratio	4.9	5.9	7.0	8.0	10.3	10.6	12.2	
Watts	380.0	505.0	615.0	740.0	905.0	950.0	1100.0	
Watts x ct ratio	1520.0	2020.0	2460.0	2960.0	3620.0	3800.0	4400.0	
Horsepower	2.0	2.7	3.3	3.9	4.9	5.1	5.9	
Amps	1.3	1.5	1.8	2.1	2.5	2.7	3.0	3.1
Amps x ct ratio	5.0	5.8	7.0	8.4	9.8	10.8	12.0	12.5
Watts	365.0	455.0	560.0	700.0	825.0	915.0	1030.0	1120.0
Watts x ct ratio	1460.0	1820.0	2240.0	2800.0	3300.0	3660.0	4120.0	4480.0
Horsepower	2.0	2.4	3.0	3.8	4.4	4.9	5.5	6.0

*ct (current transformer) ratio 20:5.

Table 3. Horsepower requirements for grinding third middlings stock with different pressures.

Roll pressure in lbs./linear inch roll surface	Input horsepower*
12.87	2.13
25.74	2.87
38.61	3.41
51.48	3.88
64.35	4.58
77.22	4.95**
90.09	5.34***
102.96	6.0****

* - Average of 8 runs.
** - Average of 6 runs.
*** - Average of 5 runs.
**** - Based on 1 run.

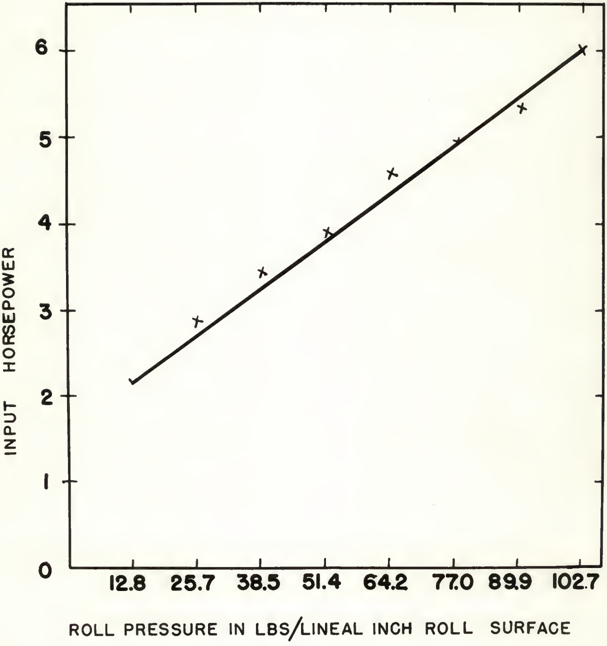


FIG. 5. HORSEPOWER REQUIREMENTS FOR GRINDING 3RD MIDDLINGS STOCK WITH DIFFERENT ROLL PRESSURES.

minute for the entire investigation.

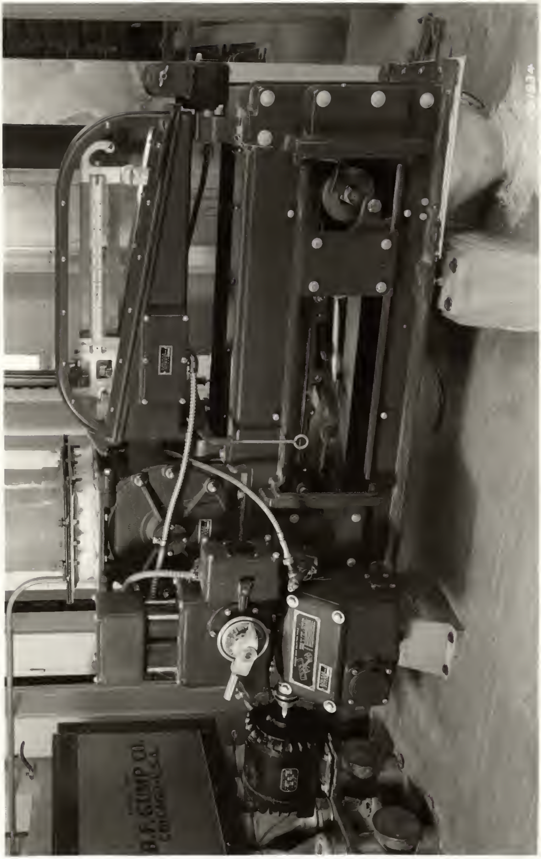
The third middlings stock was fed in a hopper and elevated to the Merchen powered feeder (Plate III). The rate of flow to the rolls was checked frequently. Figure 6 shows the flow.

The roller mill was operated with the regular roll suction and allowed to "warm up" by grinding stock through the rolls with a Statimeter pressure of 200 pounds. After obtaining favorable operating conditions, the gauges were set for 50 pounds and samples taken under each end of the roll. The extraction obtained checked satisfactorily from sample to sample unless the feeder roll was not adjusted evenly. This was checked closely and always remedied before collecting samples.

Power readings were taken while the samples were being ground at each pressure reading. The ground stock was spouted to a sack. When changing from one pressure to another, the stock was spouted to a separate container. Runs were made using pressures of 50, 100, 150, 200, 250, 300, 350 and 400 pounds. The 350 and 400-pound pressure data were not collected each time due to shortage of samples. At 400 pounds pressure, the level was beyond the capacity of the motor.

The samples ground at each pressure were obtained from 10 to 15 minutes of mill operation and each series of tests was repeated several times. After each operation, the amount of material passing through the number 11XX bolting cloth

PLATE III



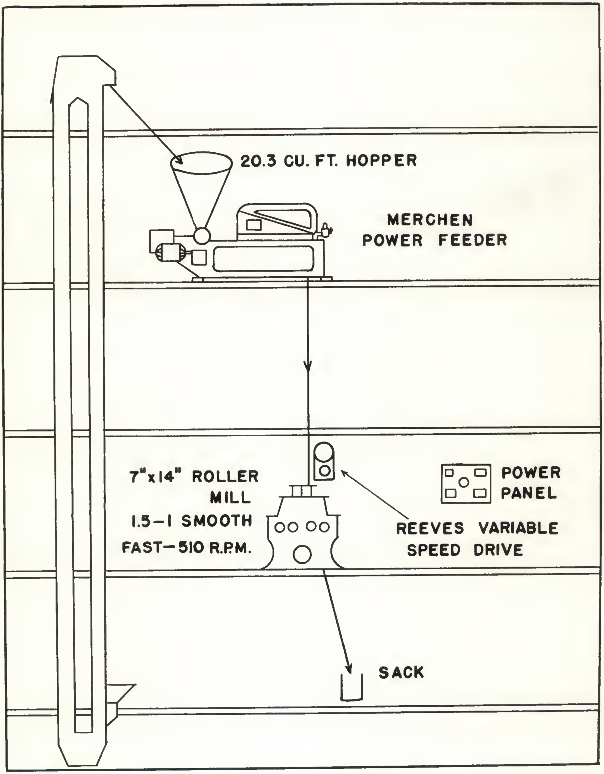


FIG. 6. RESEARCH FLOW.

was determined (Table 4). Enough flour was also obtained to conduct the physical and chemical analyses and baking tests.

Analysis of Physical and Chemical Characteristics

The Allis-Chalmers' experimental sifter was used for sifting flour through the number 11XX flour cloth. Three samples of 100 grams each were sifted for one and one-half minutes. The average of the three determinations was taken and recorded as the extraction obtained from the different roll pressures as shown in Table 4. Sufficient flour was obtained from each of these runs to make all the physical and chemical tests. The flours were sealed in metal cans until further analyses were run.

Granulation determinations were made on all samples. For plotting granulation curves, values were obtained by use of 400, 270, 200, and 150 mesh sieves, and a Rotap sifter. Wichser and Shellenberger (1948) have described the procedure for determining the granulation of flour. Using this procedure, the following results reported in Figs. 7 and 8 and Tables 5 and 6 were obtained.

The ash, protein and moisture determinations were made by methods described in Cereal Laboratory Methods (1947), and the results converted to a 14 percent moisture basis.

Farinograms were made according to the directions given by the Brabender Corporation. The absorption for the normal farinogram was determined by a titration curve using distilled

Table 4. Percent extraction of flour sifted* through 11XX silk flour cloth with different roll pressures.

Roll pressure in lbs./linear inch roll surface	Percent flour through 11XX flour cloth - 100 grams sifted one min. Five individual runs					Average
12.87	35.6	32.3	30.0	27.7	20.7	29.4
25.74	45.0	39.3	36.7	35.0	30.0	37.4
38.61	49.7	42.3	41.0	36.0	37.7	41.3
51.48	50.7	43.3	41.7	39.3	40.0	43.0
64.35	48.7	43.7	44.7	42.0	39.7	43.8
77.22	46.3	44.0	44.0	40.7	39.7	42.9
90.09	44.3	42.3	37.7	39.0	35.7	39.8
102.96**			33.7		35.3	34.0

*Allis-Chalmers experimental sifter used.
**Based on two runs.

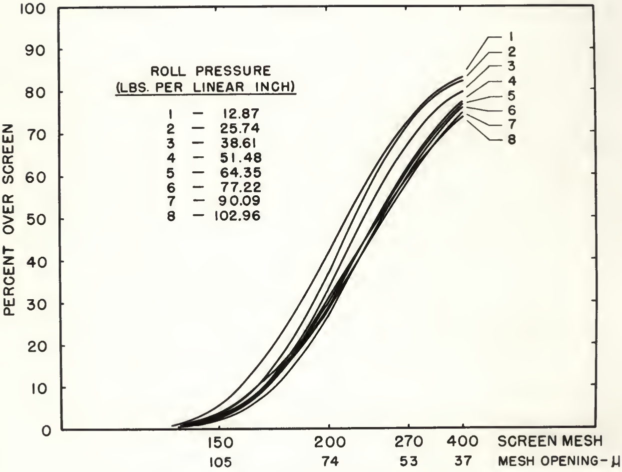


FIG. 7. GRANULATION CURVES OF COMPOSITES.

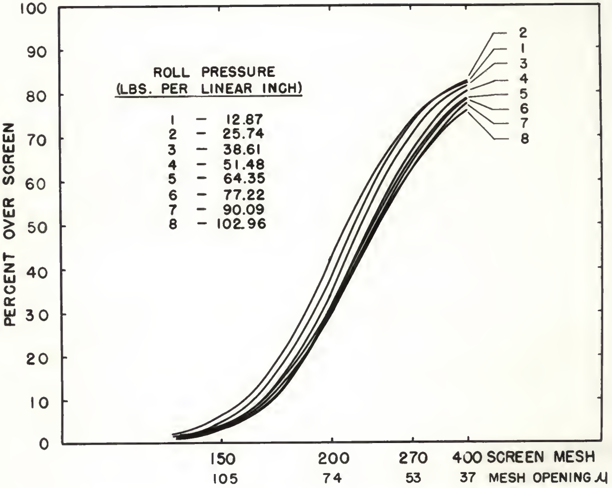


FIG. 8. GRANULATION CURVES OF SINGLE RUN.

Table 5. The optimal percentage of flour passing through the Tyler wire testing sieves* from flours produced with different pressures. Composite of 5 runs.

Roll pressure in lbs./linear inch roll surface	Wire mesh number	Sieve aperture opening in microns	Flour passing through percent
12.87	400	37	17.9
25.74			17.5
38.61			18.4
51.48			19.7
64.35			21.4
77.22			21.2
90.09			22.6
102.96**			24.0
12.87	270	53	26.9
25.74			26.6
38.61			29.7
51.48			33.1
64.35			35.5
77.22			37.0
90.09			37.8
102.96**			37.5
12.87	200	74	58.1
25.74			61.9
38.61			65.8
51.48			69.1
64.35			70.8
77.22			70.6
90.09			70.2
102.96**			68.2
12.87	150	105	93.4
25.74			95.2
38.61			95.3
51.48			95.6
64.35			95.9
77.22			95.8
90.09			96.1
102.96**			95.4

*The W. S. Tyler Ro-Tap sifter was used with these sieves.
**Based on two runs.

Table 6. Granulation curve data for flours produced with different pressures on a single run.

Roll pressure in lbs./linear inch roll surface	Wire mesh number	Sieve aperture opening in microns	Sifting time in minutes	Flour passing through percent
12.87	400	37	11	17.0
25.74			9	17.6
38.61			11	20.2
51.48			14	22.6
64.35			13	23.0
77.22			13	23.8
90.09			14	25.0
102.96			14	25.8
12.87	270	53	11	27.3
25.74			11	28.0
38.61			13	32.4
51.48			16	37.6
64.35			15	37.6
77.22			18	39.4
90.09			14	41.0
102.96				39.2
12.87	200	74	10	58.2
25.74			10	62.8
38.61			9	66.6
51.48			11	71.4
64.35			9	71.8
77.22			9	72.6
90.09			8	70.6
102.96			8	69.6
12.87	150	105	4	94.2
25.74			5	96.0
38.61			4	96.4
51.48			3	95.4
64.35			4	96.2
77.22			4	96.2
90.09			5	96.8
102.96			5	96.4

water, and bringing all doughs to the 500 Brabender unit consistency at the point of minimum mobility. The valorimeter value of each curve was determined as described by Johnson, Shellenberger and Swanson (1946).

Each flour was baked in the experimental bakery. The sponge bake was used with the following formula:

Ingredient	Sponge percent	Dough percent
Flour	70.0	30.0
Yeast	2.0	-
Arkady	0.5	-
Malted wheat flour	1.0	-
Sugar	-	5.0
Shortening	-	3.0
NaCl	-	2.0
Paniplus (calcium peroxide)	-	0.5
Dry milk solids	-	4.0

The composite of flours was baked in duplicate one-pound loaves. The samples were also baked in duplicate, using the standard method of the American Association of Cereal Chemists.

Gas production was determined by the volumetric method as described in Cereal Laboratory Methods (1947).

EXPERIMENTAL RESULTS

The effect of roll pressures on the properties of flour was investigated by the following determinations:

Horsepower consumed

Percent through 11XX flour cloth

Gassing power

Flour granulation

Ash content

Protein content

Farinogram curves and absorption

Baking tests.

The experiments reported were conducted under the following roll pressures measured in pounds per linear inch of roll surface:

12.87
25.74
38.61
51.48
64.35
77.22
90.09
102.96

Although most mills have nine-inch diameter rolls, there are some with seven-inch diameter rolls. This work was done on seven-inch rolls, and should correlate satisfactorily with nine-inch rolls.

DISCUSSION OF EXPERIMENTAL RESULTS

Measuring Roll Pressure

The results of this study showed that by the use of different roll pressures, an optimum grinding pressure could be determined. Since the tests were conducted with increment pressure changes of 50 pounds as recorded by the Statimeter gauges, the exact optimum grinding pressures were not located. However, the maximum extraction was obtained at a Statimeter pressure of 250 pounds or a pressure of 64.35 pounds per linear inch of roll surface. If this is not the optimum pressure, at least the value lies between 51.46 and 77.22 pounds per linear inch of roll surface.

The fast roll operated considerably warmer than the slow roll as is typical of all the rolls in flour mill operation.

All of the roll settings were carefully made. In the case of one gauge which fluctuated slightly, the average of the fluctuations was taken. Table 1 shows the conversion of Statimeter pressure to pounds pressure per linear inch of roll surface.

Horsepower Requirements

The horsepower required to drive the roll stand under different pressures is shown in Tables 2 and 3 and Fig. 5.

The increase in horsepower was apparent with an increase in roll pressure.

The input horsepower requirement increases proportionally with roll pressure. However, beyond a certain pressure, flour extraction decreases. This investigation showed the optimum grinding pressure to be between 51 and 64 pounds per linear inch roll surface. At this pressure, the horsepower requirements are from 3.8 to 4.5. For reasons before stated, it was not possible to determine an exact value for optimum roll pressure, but it was found to be between the values of 51 and 77 pounds per linear inch of roll surface.

Flour Extraction

The flour extraction through number 11XX bolting cloth was affected by roll pressure. As the roll pressure increased to 64.35 pounds per linear inch of roll surface, flour extraction increased. At this pressure, 43.75 percent flour extraction was obtained.

An increase in roll pressure beyond 64.35 pounds per linear inch decreased the percent extraction. The ground stock did not show visual signs of flaking until 90.09 pounds per linear inch roll pressure was reached. From this pressure on up to 102.96 pounds per linear inch, flaking was very noticeable. Table 4 and Fig. 9 show the relationship of roll pressure to flour extraction.

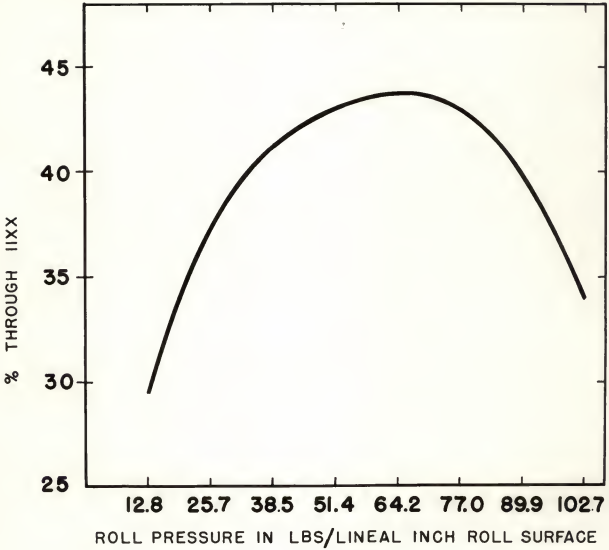


FIG. 9. PERCENT EXTRACTION OF FLOUR SIFTED THROUGH 11XX SILK FLOUR CLOTH WITH DIFFERENT ROLL PRESSURES.

Flour Granulation

Table 6 and Fig. 7 show the granulation curves of the flour produced under different roll pressures. The values are based on the average of five determinations. Within the range covered by this investigation, flour granulation decreased with increasing roll pressure. As indicated in Table 5 and Fig. 8, the granulation curves for the single run are similar to the composite of five runs.

Ash

The relation of ash to the flours produced with different pressure shows a slight decrease in ash as the roll pressures increase. Table 7 and Fig. 10 show this relationship. One test was made with third middlings having considerably more ash than the others. No significant decrease was shown with increased pressure on this sample.

Protein

The relationship of protein to the flour produced under different grinding pressures is shown in Table 8 and Fig. 11. The protein content of the flours decreased slightly with increasing pressures. One case when the ash content was higher than the other tests, the protein content decrease was not

Table 7. The relationship of the ash content to the flour produced from different pressures, based on an average test. (Original ash of third middlings, 0.532 percent.)

Roll pressure in lbs./linear inch roll surface	Percent ash*
12.87	0.43
25.74	.42
38.61	.40
51.48	.40
64.35	.38
77.22	.38
90.09	.37

*Results reported on 14 percent moisture basis.

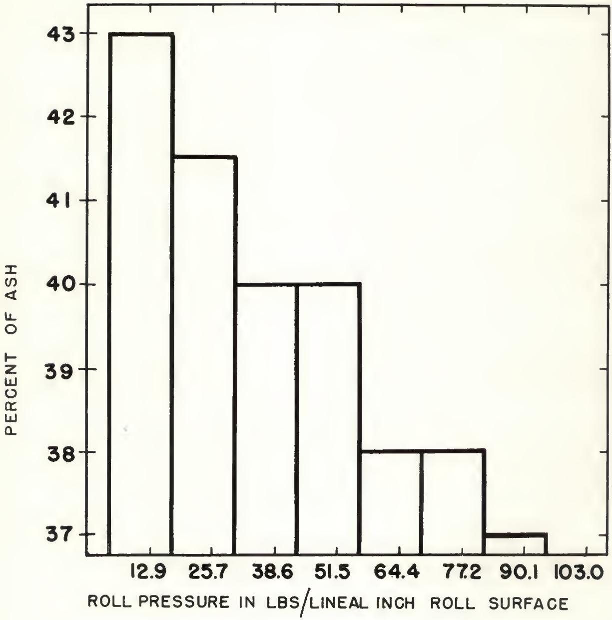


FIG. 10. RELATIONSHIP OF THE ASH CONTENT TO THE FLOURS PRODUCED FROM DIFFERENT ROLL PRESSURES ON AN AVERAGE TEST.

Table 8. The relationship of protein content to the flours produced from different pressures, based on an average test. (Original protein on third middlings, 10.65 percent.)

Roll pressure in lbs./linear inch roll surface	Percent protein content*
12.87	10.5
25.74	10.4
38.61	10.4
51.48	10.2
64.35	10.3
77.22	10.2
90.09	10.1

*Results based on 14 percent moisture basis.

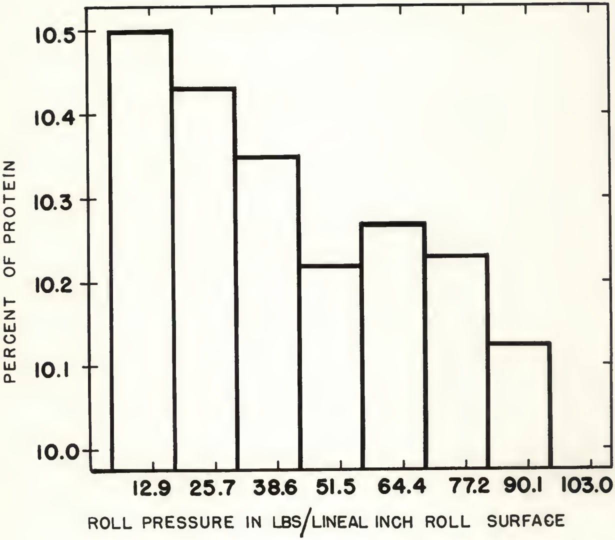


FIG. 11. RELATIONSHIP OF PROTEIN CONTENT TO THE FLOURS PRODUCED FROM DIFFERENT ROLL PRESSURES ON AN AVERAGE TEST.

significant.

All of the analyses were run on the 11XX flour cloth. Since the overs were removed, there is no doubt but that the protein was lost to the overs.

Gas Production

Table 9 and Fig. 12 show the relationship of the gas production on the composite flours produced from different roll pressures. Table 10 and Fig. 13 are for one run.

The granulation studies showed that the flours became finer as the pressures increased and that the susceptibility of the particles to enzyme attack becomes greater with increasing roll pressures on the flour particles. Thus, an increased amount of gas is formed during baking because more starch granules probably are ruptured as the pressures increase, making the flours more susceptible to the action of alpha- and beta-amylase.

Farinogram Curves and Absorption

The relation of farinogram curve characteristics to flours produced from third middlings stock, with different pressures, is shown in Plates IV and V. The differences between curve patterns are small. The 500 unit line is reached in the farinogram curve pattern after three and one-half minutes

Table 9. The relationship of gas production to the unmalted flours produced from different grinding pressures of the composite (five runs).

Roll pressure in: lbs./linear inch: roll surface	Gas production in mm of mercury					
	Hours					
	1	2	3	4	5	6
12.87	94	212	297	316	328	339
25.74	96	215	288	306	317	327
38.61	96	218	295	311	322	333
51.48	95	215	296	315	327	337
64.35	94	215	299	319	332	340
77.22	96	218	307	330	345	354
90.09	95	218	309	328	339	335
102.96*	94	219	318	344	356	358

*Based on two runs.

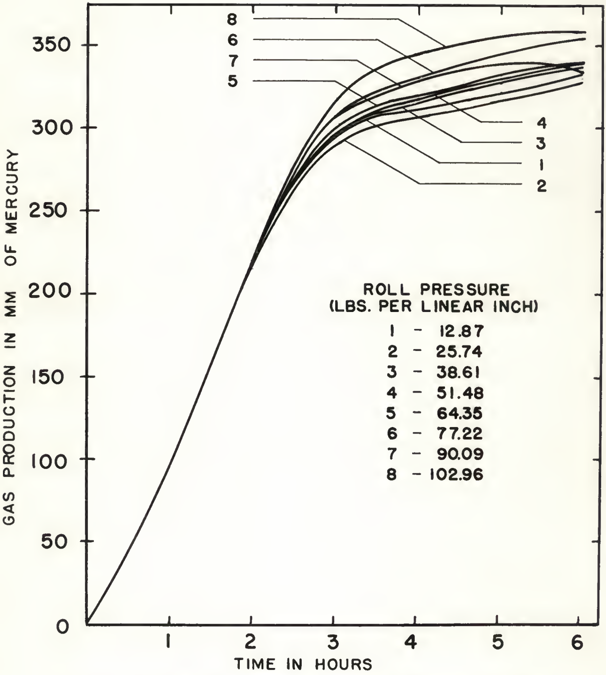


FIG. 12. RELATIONSHIP OF GAS PRODUCTION TO THE FLOURS PRODUCED FROM DIFFERENT GRINDING PRESSURES OF THE COMPOSITE (5) RUNS.

Table 10. The relationship of gas production to the unmalted flours produced from different grinding pressures on one single run.

Roll pressure in: lbs./linear inch: roll surface	Gas production in mm of mercury					
	Hours					
	1	2	3	4	5	6
12.87	90	197	301	314	328	339
25.74	102	215	287	302	317	319
38.61	94	215	290	309	322	333
51.48	98	216	304	325	327	345
64.35	95	212	307	325	332	336
77.22	101	221	318	340	345	356
90.09	99	224	322	344	339	351
102.96	94	210	323	351	356	369

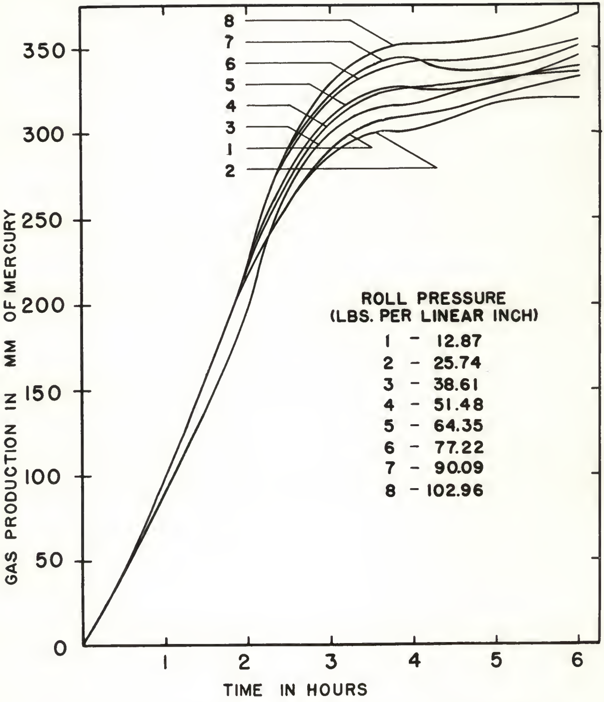
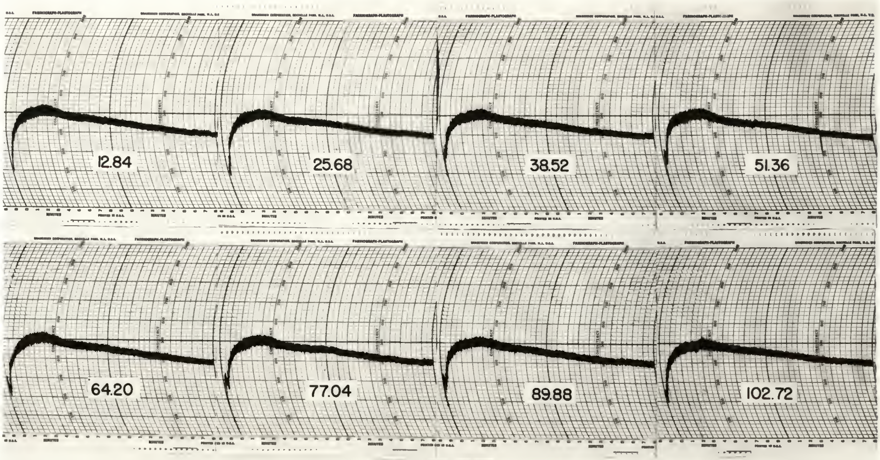


FIG. 13 RELATIONSHIP OF GAS PRODUCTION TO THE FLOURS PRODUCED FROM DIFFERENT GRINDING PRESSURES ON ONE SINGLE RUN.

EXPLANATION OF PLATE IV

Farinograph curves of a single run of third middlings flour produced from different roll pressures. The roll pressure in pounds per linear inch roll surface is given on the curves.

PLATE IV

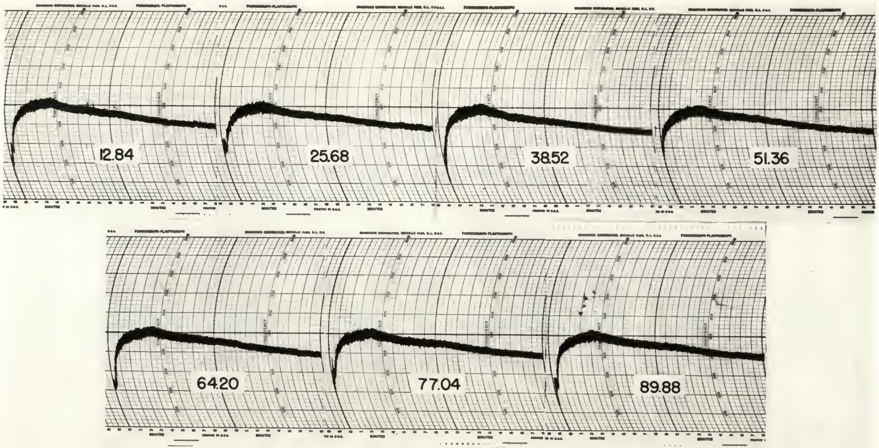


SINGLE RUN

EXPLANATION OF PLATE V

Farinograph curves of the composite of five runs of third middlings flour produced from different roll pressures. The roll pressure in pounds per linear inch roll surface is given on the curves.

PLATE V



COMPOSITE

of mixing on the single run flours. The composite flours had a three and one-half to four-minute farinogram mixing time.

The farinogram curves are primarily important for determining flour absorption and mixing tolerance. Absorption increased as roll pressures increased in milling the flour, as shown in Table 11 and Figs. 14 and 15. There was no relationship between the valorimeter reading of the curves and roll pressures used to produce the flours (see Table 11).

Bake

A comparison of the loaves of bread baked from the flour manufactured with different pressures is shown in Plates VI and VII. A summary of the baking data is given in Tables 12 and 13. Plate VI and Table 12 are for a single run. Plate VII and Table 13 are for a composite of five runs.

One of the most important characteristics sought in a loaf of bread is volume, assuming that the loaf grain and texture are good. In this experiment, the loaf volume differences were slight. This probably was due to the uniform protein content of the flours used for the bake. The protein content of the flours did not vary more than 0.3 percent.

The grain, texture, external symmetry and loaf weight of the bread baked from the individual samples and the composite were of no significant difference. Since the flour was unbleached, all of the bread had a slight yellow cast.

Table 11. The relationship of absorption and valorimeter value to the flours produced from different grinding pressures on a single run and composite run.

Roll pressure in lbs./linear inch roll surface	Farinogram	
	Absorption* percent	Valorimeter value units
	Single Run	
12.87	60.0	52
25.74	60.1	51
38.61	61.2	52
51.48	61.4	50
64.35	61.1	51
77.22	62.0	52
90.09	63.4	52
102.96	63.7	52
	Composite Run	
12.87	61.0	52
25.74	61.0	52
38.61	61.0	50
51.48	61.2	51
64.35	61.6	52
77.22	61.4	52
90.09	63.0	52

*Results reported on 14 percent moisture basis.

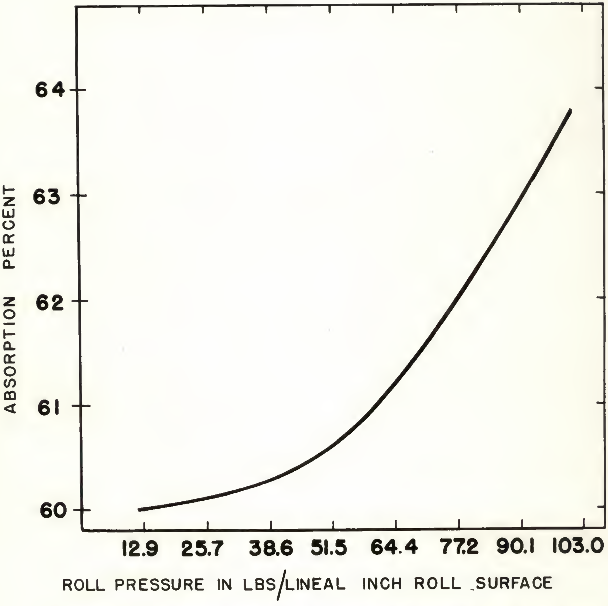


FIG. 14. RELATIONSHIP OF ABSORPTION TO THE FLOURS PRODUCED FROM DIFFERENT GRINDING PRESSURES ON A SINGLE RUN.

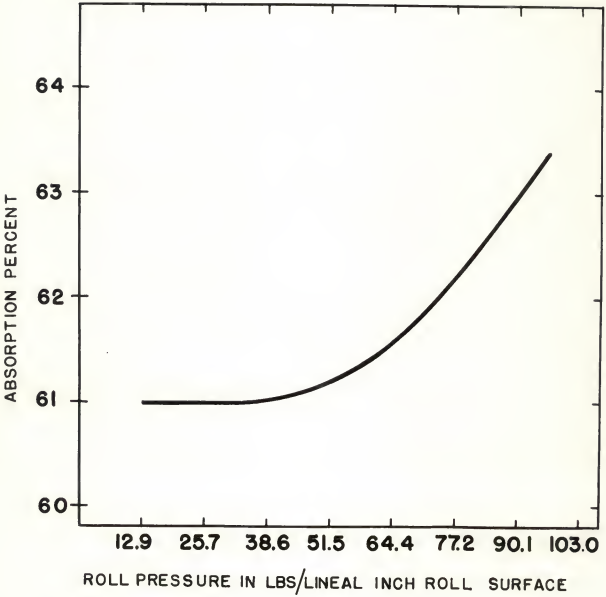


FIG. 15. RELATIONSHIP OF ABSORPTION TO THE FLOURS PRODUCED FROM DIFFERENT GRINDING PRESSURES ON A COMPOSITE RUN.

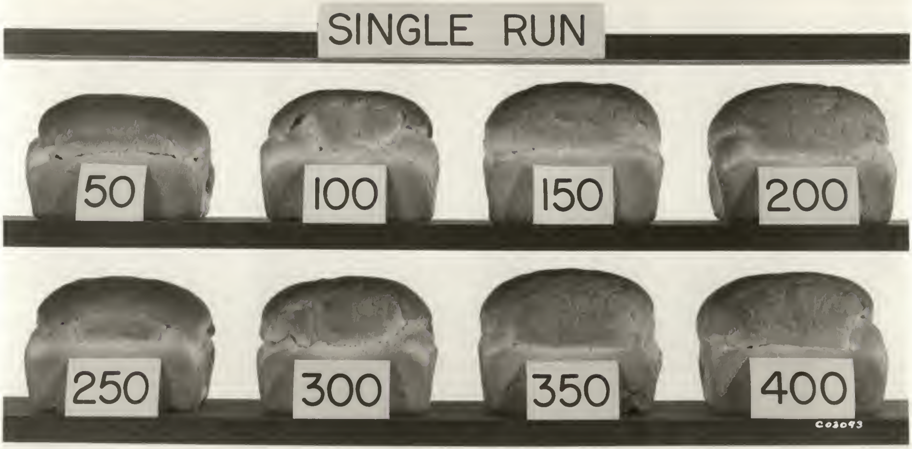
EXPLANATION OF PLATE VI

Comparison of loaves baked from a single run of third middlings flour produced from different roll pressures.

The legend for the symbols is as follows:

Loaf designation	Roll pressure in lbs./linear inch roll surface
50	12.87
100	25.74
150	38.61
200	51.48
250	64.35
300	77.22
350	90.09
400	102.96

PLATE VI



EXPLANATION OF PLATE VII

Comparison of loaves baked from the composite of fine runs of third middlings flour produced from different roll pressures. The legend for the symbols is as follows:

Loaf designation	Roll pressure in lbs./linear inch roll surface
50	12.87
100	25.74
150	38.61
200	51.48
250	64.35
300	77.22
350	90.09

PLATE VII

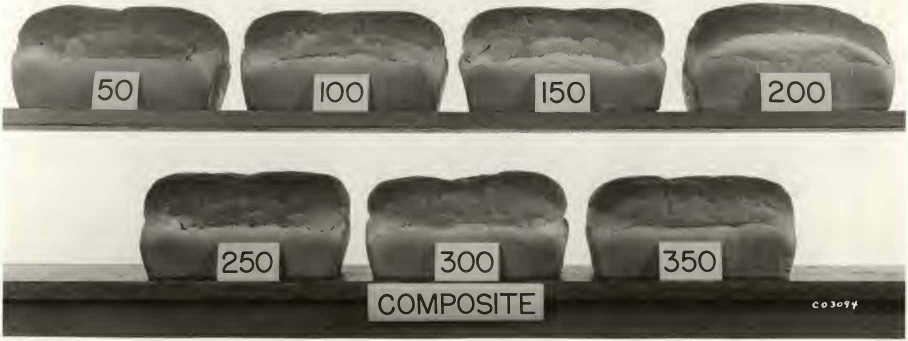


Table 12. Summary of the baking data for the single run of third middlings flour produced from different roll pressures.

Roll pressure in lbs./linear inch roll surface	Loaf number	Loaf* volume cc	Loaf weight grams	Grain	Texture	External symmetry
12.87	50	788	150	85	85	poor
25.74	100	783	151	85	85	poor
38.61	150	890	150	88	88	good
51.48	200	895	143	88	88	very good
64.35	250	820	150	85	85	fair
77.22	300	788	150	88	85	fair
90.09	350	885	148	88	88	good
102.96	400	845	146	88	88	very good

*Average of duplicate bake.

Table 13. Summary of the baking data for the composite of five runs of third middlings flour produced from different roll pressures.

Roll pressure in lbs./linear inch roll surface	Loaf number	Loaf* volume cc	Loaf weight grams	Grain	Texture	External symmetry
12.87	50	2563	445	88	88	fair
25.74	100	2450	448	85	85	good
38.61	150	2575	450	90	88	good
51.48	200	2500	457	90	85	good
64.35	250	2500	455	88	83	fair
77.22	300	2403	457	82	80	good
90.09	350	2388	459	88	83	poor

*Average of duplicate bake.

SUMMARY AND CONCLUSIONS

Hard red winter wheat, third middlings stock was ground with different roll pressures. Studies were made of horsepower requirements with different pressures and the flour produced was determined. Chemical and physical tests were performed on the flours produced with different roll pressures. The Statimeter (Hughes patent 398,687) gauge was found satisfactory for this work. The Wolf roller mill was used with a fast roll speed of 510 r.p.m. and a slow roll speed of 345 r.p.m. This gave a 1.48:1 differential. The rate of flow was kept constant at three pounds per minute. The conclusions reached in this investigation are:

1. The optimum percent extraction of flour was obtained between a roll pressure of 51 and 77 pounds per linear inch roll surface. Pressures above the optimum give less extraction. The percent throughs at optimum pressure was 43.75.

2. The input horsepower requirements increase proportionately with an increase in roll pressure.

3. Flour granulation was affected by roll pressure. As the pressure increased the flour granulation became finer.

4. The gassing power increased with increasing roll pressure. This probably was due to the increasing percent of ruptured starch granules.

5. The flour absorption increased with pressure. This was logical since the flour granulation became finer with

increased pressure, thus making a greater amount of surface area.

6. The protein content for the flours manufactured with increasing roll pressures, decreased with increasing pressures.

7. The trend of the ash content was similar to the protein. The flours decreased in ash with increasing pressures.

This was basic research and has accomplished the purpose of the investigation. A suitable system for making grinding tests was set up. Further study would be desirable.

ACKNOWLEDGMENTS

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GRINDING WITH CONTROLLED ROLL PRESSURE

by

ARLIN BRUCE WARD

B. S., Kansas State College
of Agriculture and Applied Science, 1942

AN ABSTRACT

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1951

The purpose of this study was to correlate the results of pertinent investigations already reported, and to determine other basic requirements for grinding with maximum efficiency with controlled pressures.

The effect of different roll pressures was studied using third middlings stock from hard red winter wheat. Statimeters were used to measure pressures on a pair of 7-inch x 14-inch smooth rolls having a differential of 1.5:1 with a fast roll speed of 510 r.p.m.

The Statimeter is an instrument for measuring mechanical forces, using the principles of the practical incompressibility of liquids. An annular ring of rubber is filled with a mixture of glycerine and water which are de-aerated. The annular ring consists of two members which telescope one within the other as pressure is applied. The hermetically sealed liquid in the rubber tube is connected to a Bourdon type pressure gauge, especially constructed to withstand shocks and vibrations. When mounted, the Statimeters record on an indicating dial the pressures exerted on the casings.

The gauge pressure recorded the tension of each rod and from this the roll pressure in pounds per linear inch of roll surface was calculated. The pressures ranged from 12.87 to 102.96 pounds per linear inch of roll surface.

The following conclusions were reached from this investigation:

1. The optimum percent extraction of flour was obtained

between a roll pressure of 51 and 77 pounds per linear inch roll surface. Pressures above the optimum give less extraction. The percent throughs at optimum pressure was 43.75.

2. The input horsepower requirements increase proportionately with an increase in roll pressure.

3. Flour granulation was affected by roll pressure. As the pressure increased the flour granulation became finer.

4. Increasing roll pressure raised the rate at which the amylases converted the flour starch into sugar. In other words, the gassing power values were increased by increased roll pressures.

5. The flour absorption increased with pressure. This was logical since the flour granulation became finer with increasing pressure, thus making a greater amount of surface area.

6. The protein content for the flours manufactured with increasing roll pressures decreased with increasing pressures.

7. The trend of the ash content was similar to the protein. The flours decreased in ash with increasing pressures.